THE MOST LUMINOUS STAR FORMATION REGIONS IN THE GALAXY

D.T. Jaffe[1], R. Genzel[2], D.A. Harper[3], A.I. Harris[2], P.T.P. Ho[4]
[1]Space Sci. Lab., U. of California, Berkeley, CA, 94720,USA
[2]Dept .of Physics, U. of California, Berkeley, CA, 94720,USA
[3]Yerkes Observatory, Williams Bay, WI, 53191, USA
[4]Dept. of Astronomy, Harvard University, Cambridge, MA 02138,USA

We present new far-IR and submillimeter broad-band and spectroscopic results on the dense and very luminous cores of massive star formation regions. The best-studied region, W51, contains one core around the source IRS2 and another around W51 MAIN. Our earlier submillimeter continuum mapping has shown that these two cores are very massive (2-4 $\times 10^4$ $M_\odot$) and have *average* densities of $n_{H_2} \sim 10^5$ over their inner parsec. New far-IR maps show that both cores are very luminous (L(MAIN) $\sim 2 \times 10^6$ $L_\odot$; L(IRS2) $\sim 4\times10^6$ $L_\odot$). Observations of the (1,1) and (2,1) transitions of NH_3, indicate high kinetic temperatures (200-400 K) for the quiescent gas in the inner several arc seconds (0.1 pc) of both cores. Spectroscopy of the 370 μm J = 7 → 6 and 163 μm J = 16 → 15 transitions of CO toward the cores allows us to characterize the hot high velocity material seen previously on the H_2O maser transitions and not readily visible in the low J transitions of CO. The high velocity flow in IRS2 is $\sim$ 60 times more massive than the very similar outflow in the $\sim$ 30 times less luminous Orion/KL core. The mass loss rate is $\sim$ 30 times greater than in Orion. Additional observations of W49 allow us to draw a few general conclusions about the most luminous star formation regions in our galaxy: (1) The luminous cores are 10^2-10^3 more massive than the Orion core with the same density. (2) Outflows and warm regions in these cores have physical conditions similar to those in their less luminous counterparts but far more mass is involved in the flows.

MASSIVE STAR FORMATION IN W49

J. Dreher[1], S. Vogel[2], S. Terebey[3], W.J. Welch[2]
[1]Dept. of Physics, MIT, Cambridge, MA 02139, USA
[2]Radio Astron. Lab., U. California, Berkeley, CA 94720, USA
[3]HAO, Natl. Ctr. for Atmospheric Research, Boulder, CO 80307, USA

W49 is the most luminous H II region complex in the galaxy. VLA maps in the continuum reveal a complex of more than two dozen compact H II regions, including a ring-like distribution of a dozen such regions within a volume of 1 pc. In addition to the VLA maps, we have obtained

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high resolution maps in this field with the Hat Creek Millimeter Interferometer in the following molecular lines: HCO+(1-0), $H^{13}CO$+(1-0), SiO(v = 0, J = 2-1), SiO(v = 1, J = 2-1), $H^{13}CN$(1-0), $HC^{15}N$(1-0), SO_2 [8(3,5)-9(2,8)], SO_2[8(1,7)-8(0,8)], SO[2(2)-1(1)], and CH_3CH_2CN[10(1,10) -9(1,9)], all near 3 mm wavelengh. These maps will be discussed. The HCO+distribution corresponds to the larger scale structures observed in the continuum maps. In contrast the SO and SiO sources are quite compact. Using the detailed molecular line results obtained in the ORION/ KL region as a guide, we are able to identify these latter sources as regions in which the star formation is at an earlier stage, regions where there are outflows.

RODRIGUEZ: Do you think that these individual H II regions are ionized by different stars or could you have a clumpy structure and a central, very powerful star ionizing all the regions? If you favor the multiple star model, how do you explain the simultaneous formation and similarity of the stars?

WELCH: The free-free flux of each object requires at least one O star to be embedded in each clump to provide the necessary ultra-violet flux for the ionization. A single central powerful star ionizing the clumps is not likely because the dilution in solid angle would be more than a factor of 100. The powerful star would have to have more than 100 times the ultra-violet flux of an O5 star. The appearance of the coherent structure can be partly understood by supposing that the parent cloud collapsed along the direction of angular momentum or magnetic field that is evident in the bipolar flows. However, I do not understand the formation of so many O stars around the apparent perimeter of the flattened structure.

ZINNECKER: A comment. The strikingly coherent structure of the "necklace" or H II regions in W49 prompts the speculation that some object with a large momentum plunged into the W49 molecular cloud.

WELCH: Yes, it is interesting to note that the extension of the line which is normal to the major axis of the "necklace" to the Southwest leads to another major region of ionization. Perhaps this is the path of the object of your speculation.

TERZIAN: a) Did you detect any non-thermal sources, perhaps due to SNR in the region you observed? b) What is the derived electron temperature of the H II sources from your recombination line observations?

WELCH: The only probable SNR is the one you, Metzger, and Schraml reported some years ago which is about 50 pc to the east of the region which we are discussing here in detail. None of the individual components in this latter region shows the non-thermal spectrum of a SNR. The electron temperatures are on the order of 8000 K.

MOUSCHOVIAS: Is the line profile for HCO^+ asymmetric?

WELCH: Yes. This is partly due to the considerable HCO^+ absorption of the continuum emission at the lower velocities due to foreground gas.

MATHIEU: You put a limit on the rotation of the necklace of about 10 km/sec. What is the measured velocity dispersion of the ensemble of O star/H II regions?

WELCH: 10 km/sec is a rough upper limit on the rotation velocity. We have not yet made a sufficiently careful study of the internal motions within each H II region to give a clear answer regarding the dispersion of the ensemble.

PUDRITZ: Have low luminosity infrared sources been found or searched for in your proposed ring structure?

WELCH: There is one strong 20 μ peak near the bipolar and H_2O maser source. Otherwise, there is a smooth background of 20 μ emission over the "ring" in which the individual H II regions do not appear as point sources. This is consistent with a large dust extinction in front of and within the region.

$^{12}C^{18}O$ IN OMC-1: KINEMATICS, MOLECULAR COLUMN DENSITY, AND KINETIC TEMPERATURE DISTRIBUTION

T.L. Wilson, E. Serabyn, C. Henkel, C.M. Walmsley
Max-Planck-Institut für Radioastronomie
Auf dem Hügel 69
D-5300 Bonn 1, Federal Fepublic of Germany

A fully sampled map of size ∿1'×3' (R.A. Dec.), centered on BN-KL has been made in the J = 1-0 line of $^{12}C^{18}O$ with 21" angular resolution. The $^{12}C^{18}O$ emission is concentrated in a ≦ 40" wide continuous strip running S to NE. Several maxima are superposed on the ridge, but none exceeds the average emission level by more than 40%. There is no intense peak of $^{12}C^{18}O$ J = 1-0 line emission centered on BN-KL, in contrast to maps of the dust emission. The dust and $^{12}C^{18}O$ results can be reconciled with a constant (CO/H_2) ratio if there are variations in the kinetic temperature and column density of ∿50%. Peaks in both temperature and column density are then located near BN-KL, and 90" to the south. From the estimated CO column density, about 10% of the carbon is in the form of CO. Near the BN-KL region, the $^{12}C^{18}O$ line profiles tend to become wider. These wider lines appear to be superposed on a weak, 18 km s^{-1} (FWHP) wide pedestal. In regions 40" NE and 30" S of BN-KL, the $^{12}C^{18}O$ lines have widths of less than 2 km s^{-1}. Presumably, these are the locations of high density, quiescent molecular gas. The radial velocity of the CO emission increases from 6.5 km s^{-1} (at 90" S) to 10.5 km s^{-1} (at 60" NE) of BN-KL. Close to BN-KL, however, there is evidence that this trend is reversed.

HASEGAWA: What is the typical optical depth of the $C^{18}O$ line? It is possible that the small-scale clumps which are optically thick in the $C^{18}O$ line cause the different appearance of the $C^{18}O$ and 400 μm maps?

WILSON: For example, in BN-KL, the beam dilution in the "Hot Component"

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